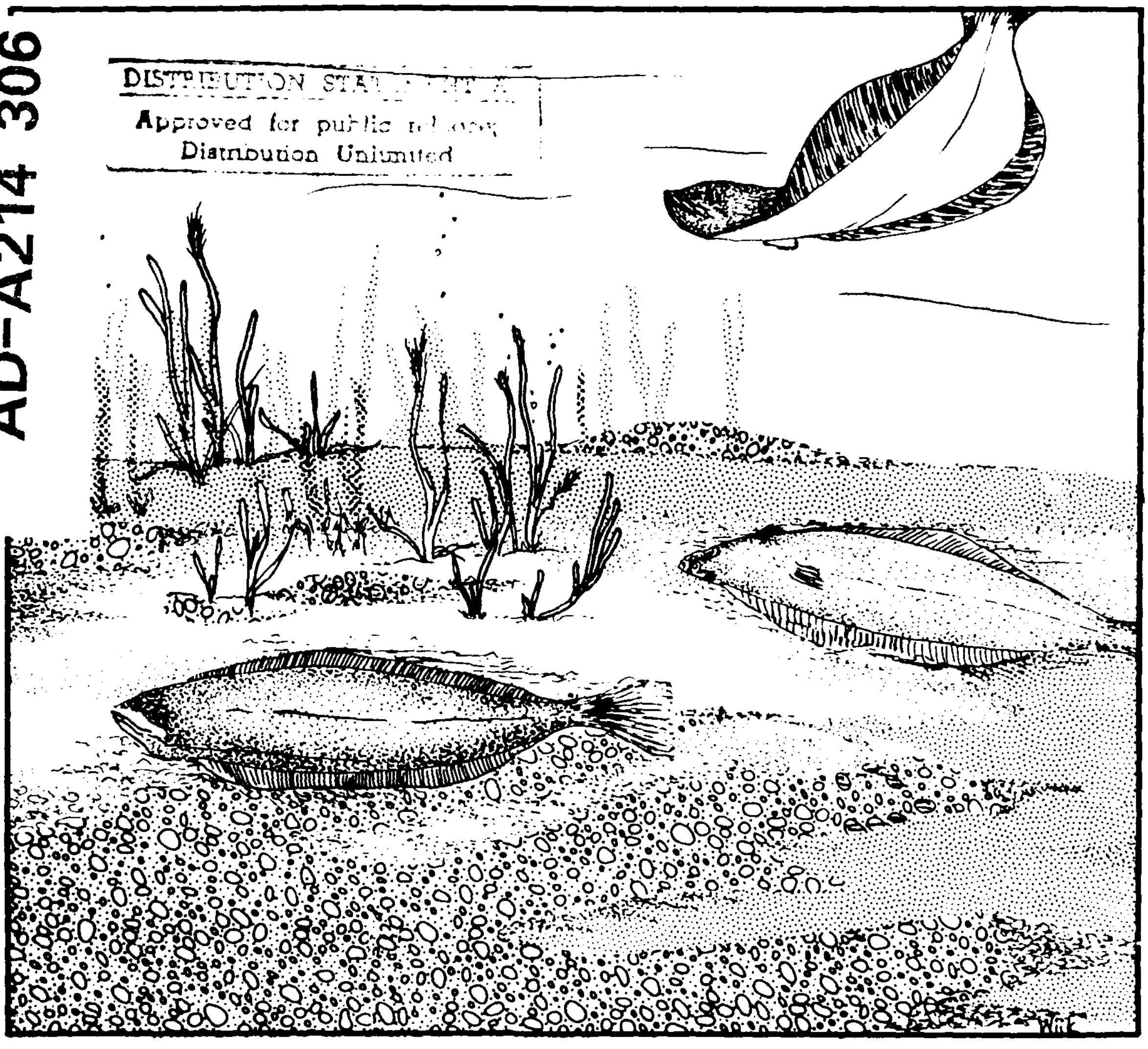
(2)

Biological Report 82 (11.112)
August 1989

TR EL-82-4

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

SUMMER AND WINTER FLOUNDER



Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

Fish and Wildlife Service
U.S. Department of the Interior

Biological Report 82(11.112)
TR EL-82-4
August 1989

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

SUMMER AND WINTER FLOUNDER

by

Barbara H. Grimes, Melvin T. Huish, and J. Howard Kerby
U.S. Fish and Wildlife Service
North Carolina Cooperative Fishery Research Unit
Department of Zoology
North Carolina State University
Raleigh, NC 27695

and

David Moran
U.S. Fish and Wildlife Service
National Wetlands Research Center
1010 Gause Boulevard
Slidell, LA 70458

Project Manager
Edward Pendleton
U.S. Fish and Wildlife Service
National Wetlands Research Center
1010 Gause Boulevard
Slidell, LA 70458

Performed for

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers
Vicksburg, MS 39180

and

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
National Wetlands Research Center
Washington, DC 20240

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

Information Transfer Specialist
National Wetlands Research Center
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Boulevard
Slidell, LA 70458

or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
Post Office Box 631
Vicksburg, MS 39180

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

We would like to express our sincere thanks to Dorothy Wright for typing this manuscript. Also, we would like to thank Dr. Larry Ray Grimes for technical assistance and advice. We also thank John Musick of the Virginia Institute of Marine Science and Paul Scarlett of the New Jersey Division of Fish and Game for reviewing the report.

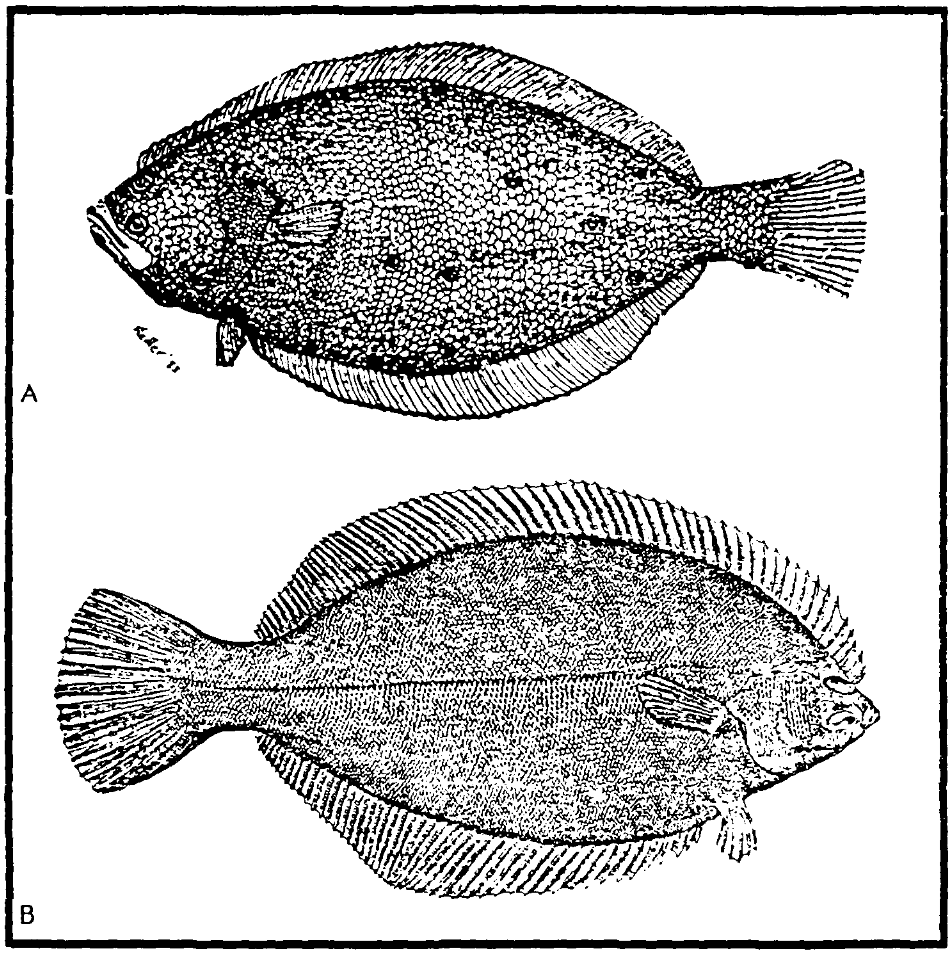


Figure 1. A. Summer flounder (Powell 1974), B. Winter flounder (Martin and Drewry 1978).

SUMMER AND WINTER FLOUNDER

NOMENCLATURE/TAXONOMY/RANGE

Summer Flounder

Scientific name...........*Paralichthys dentatus*
Preferred common name...........Summer flounder (Figure 1A)
Other common names...........Flounder, fluke, plaice fish, plaice, plaise, splaice, chicken halibut, flounder of New York, common flounder, brail, turbot, flatfish, longtoothed flounder
Class.....................Osteichthyes
Order................Pleuronectiformes
Family.......................Bothidae
Geographic range: The summer flounder prefers estuarine and shelf waters of the Atlantic Ocean. It is found between Nova Scotia and the southeastern coast of Florida but is most abundant from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina (Hildebrand and Schroeder 1928). Distribution in

the mid-Atlantic region is shown in Figure 2.

Winter Flounder

Scientific name.....*Pseudopleuronectes americanus*
Preferred common name...........winter flounder (Figure 1B)
Other common names...........Flatfish, blackback, Georges Bank flounder, lemon sole, flounder, sole, rough flounder, plie rouge, carrelet, halibut, holibut, dab.
Class....................Osteichthyes
Order................Pleuronectiformes
Family.................Pleuronectidae
Geographic range: The winter flounder has a broad range, occurring from Buttle Harbor and Windy Tickle, Labrador, to Beaufort, North Carolina, but is most common in estuaries between the Gulf of St. Lawrence and Chesapeake Bay. Distribution in the Mid-Atlantic Region is shown in Figure 2.

MORPHOLOGY/IDENTIFICATION AIDS

Summer Flounder

The body of the summer flounder is laterally flattened; a margin of the preopercle is free; and the eyes are on the left side. The bases of both pelvic fins are short. The ocular side of the fish ranges from tan to dark brown and has numerous ocellated spots. Five prominent spots are arranged in two triangles with a common apex on the lateral line; however, this configuration is generally lacking in larger specimens. The fish are able to blend into their background by adapting to the texture and color of the substrate on which they live.

Meristic characteristics: Dorsal rays, 80-98; anal rays, 63-78; pectoral rays, 10-13; vertebrae 40-43 (Smith and Daiber 1977); gill rakers on lower limb of first arch 14-19. Average head length and average upper jaw length are contained 3.96 and 2.05 times, respectively, in standard length (SL) (Hildebrand and Schroeder 1928). The scales are ctenoid. Late postlarvae of summer flounder have a well-defined band of black pigment along the anterior two-thirds of the anal fin and a similar band along the anterior four-fifths of the dorsal fin (Figure 3d) which are lacking in the southern flounder (Paralichthys lethostigma) and the gulf flounder (P. albigutta). Summer flounder postlarvae typically have 40-42 total vertebrae while southern flounder postlarvae have 37 or 38 and gulf flounder postlarvae have 36-38. Summer flounder postlarvae have 81-94 dorsal rays and 61-74 anal rays, while gulf flounder postlarvae have 72-82 dorsal rays and 53-63 anal rays (Deubler 1958).

Winter Flounder

The winter flounder's body is ovate and laterally compressed. The eyes are on the right side, separated by a narrow scaled ridge; the upper eye is near the edge of the head. The mouth is of moderate size and the length of the maxillary on the blind side is less than one-third that of the head. Winter flounder are olive green to reddish-brown in color and sometimes have a few rusty spots. The lateral line is nearly straight. The dorsal fin originates opposite the forward edge of the eye and is of nearly equal height throughout its length.

Meristic characteristics: Dorsal rays 56-81; anal rays 47-54; pectoral rays 10-11; gill rakers on lower limb of first arch, 7-8; vertebrae, 36. Average head length is 4.0 cm (Hildebrand and Schroeder 1928; Pierce and Howe 1977). The scales are ctenoid.

REASON FOR INCLUSION IN SERIES

The summer flounder is an important commercial and recreational

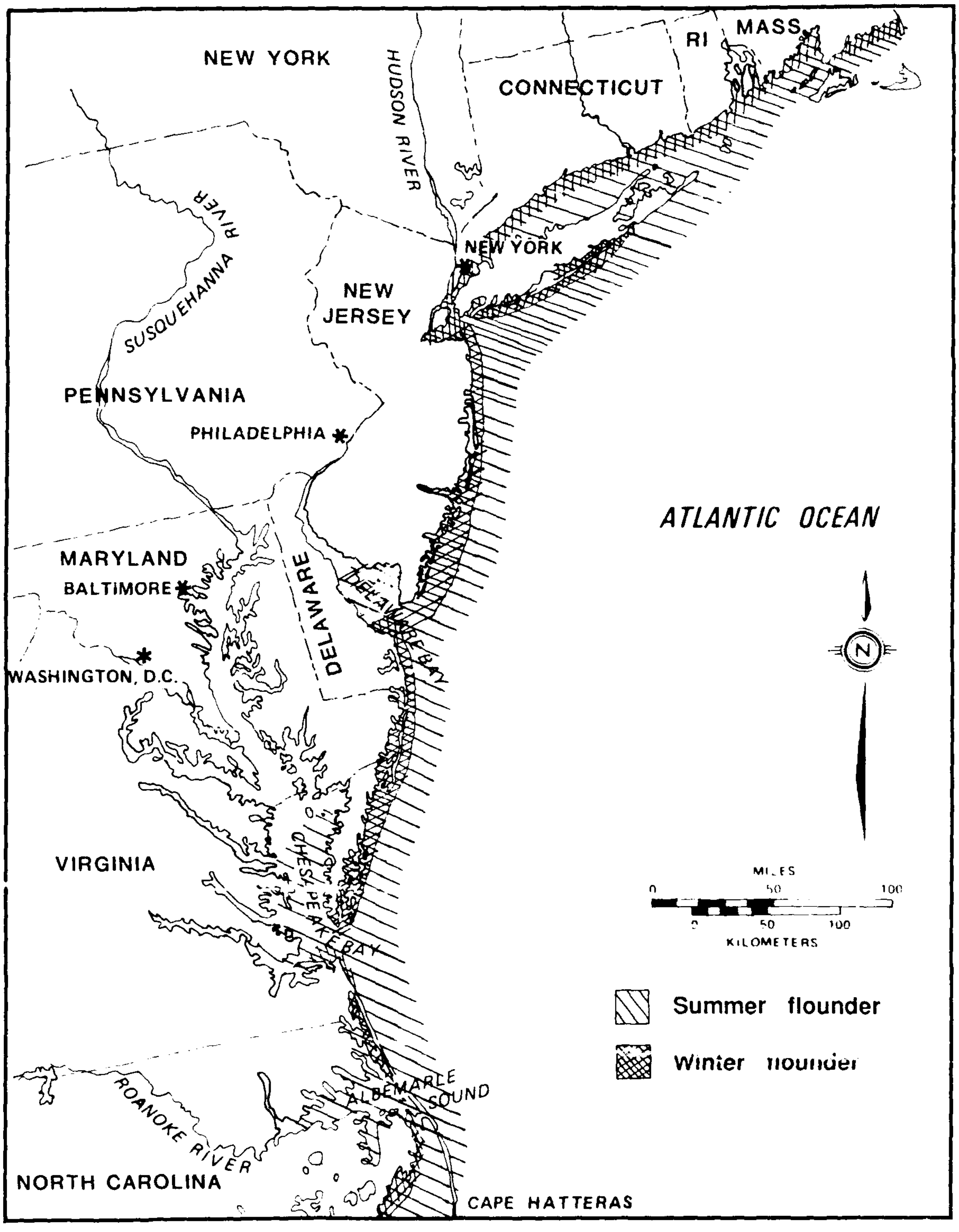


Figure 2. Distribution of the Summer and Winter flounder in the mid-Atlantic region.

species along the Atlantic seaboard of the United States and is the major recreationally caught flounder of the mid-Atlantic inshore waters. There are three major commercial fisheries: the inshore summer fishery; the offshore winter fishery; and a fall and winter trawl fishery inside the 20-fathom (36-m) contour that developed on the Virginia and North Carolina coast in the 1960's (Hildebrand and Schroeder 1928; Scarlett 1981).

LIFE HISTORY

Reproductive Physiology/Strategy

Adult female summer flounder, on the average, are 60 mm longer (in total length, TL) than males at first attainment of sexual maturity in the Mid-Atlantic Bight (Morse 1981). The summer flounder appears to become sexually mature by the age of II (Morse 1981). Gonads of summer *flounder ripened from* mid-August through November in the Delaware Bay; the fish moved offshore to spawn in the winter (Smith and Daiber 1977). Morse (1981) reported that summer flounder have a protracted spawning season of variable duration with early maturation, high fecundity, serial spawning, and extensive migrations across the continental shelf. Life history parameters are determined by local genetic and environmental factors.

The number of maturing ova in summer flounder is highly correlated with weight and length. Fish in the Mid-Atlantic Region between 366 and 680 mm TL have an estimated 0.46 to 4.19 million ova (Morse 1981).

Total egg count of winter flounder ranged from 0.435 million for an age-III fish to 3.329 million eggs for an age-V fish captured off Massachusetts (Topp 1968). The regression equation for the relationship of fecundity to fish weight for winter flounder was as follows:

$$\ln F = 0.1605 + 1.0659 \ln W \ (N = 30)$$

where W is weight in grams.

South Atlantic Bight (Smith 1973). Adult summer flounder move back inshore to estuaries or coastal waters in the winter and spring (Wilk et al. 1980).

Spawning

In the South Atlantic Bight, spawning times and habitats of summer flounder are poorly documented. Based on collections of newly hatched larvae, commercial catch rates, and generalized coastal and shelf trawling surveys, seasonal migration patterns of adult fish have been deduced. It is known that summer flounder migrate offshore during cooler months. In late fall, winter, or early spring they spawn near the bottom of shelf waters 30-200 m deep. The genetically distinct populations north and south of Cape Hatteras may behave differently.

Between Cape Cod, Massachusetts, and Cape Lookout, North Carolina, spawning of summer flounder began in September (Smith 1973). In the survey by Smith (1973), spawning continued through December in the northern part, and through February to the south. Spawning in the Mid-Atlantic Region continues into February and March in some years and probably begins north of Chesapeake Bay and progresses southward in a cycle that ends in the South Atlantic Bight (Smith 1973). Adult summer flounder move back inshore to estuaries or coastal waters in the winter and spring (Wilk et al. 1980).

Spawning times of the winter flounder are variable, like those of the summer flounder; spawning occurs first in the southern part of the

range and progressively later towards the north in keeping with water temperatures. Spawning occurs inshore from November through June from Newfoundland to Delaware. Male winter flounder in northern (Canadian) waters showed spermatogenesis and gonad development 6 months before the spawning season (which was in May to June). Oocytes may take three years to mature. Nonreproductive individuals occur in the spawning season, but condition factors are less in these fish. They may be conserving resources to spawn after a later feeding season with abundant food where their condition factor is higher (Burton and Idler 1984).

Saila (1961) showed with tagging studies that winter flounder returned to the tagging locality with high frequency over one year of recovery data. Fish dispersed from the breeding grounds in summer and returned in winter. The same breeding area was not always successfully located (Saila 1961).

Winter flounder spawn in shallow inshore waters (Jeffries and Johnson 1974). Spawning occurs at night (Breder 1922). In observations by Breder (1922) in the laboratory, spawning is preceded by extensive swimming in spirals. The females extrude eggs in wide counterclockwise spirals due to the centrifugal force (Breder 1922).

Eggs

Eggs of the summer flounder are pelagic. Incubation time in the laboratory was 9 days at 5 °C and 2-3 days at 21 °C. Mean diameter of mature unfertilized eggs is 0.98 mm. Yolk occupies about 95% of the egg volume (Johns et al. 1981).

Winter flounder eggs are minute, demersal, and adhesive, sinking to the bottom (Breder 1924). The adhesive eggs averaged 0.81 mm (Breder 1924) or 0.61 mm (Topp 1968) in modal diameter. They clump together after fertilization, thus often becoming distorted and ovoid in shape (Breder 1924).

Larvae

Notochord length of summer flounder was about 3.0 mm at hatching in the laboratory and was about 3.6 mm when yolk-sac absorption was complete (Johns et al. 1981). Growth until the absorption of the yolk sac is complete is not temperature dependent. Larvae that hatch at both 11 °C and 21 °C grow to about 3.6 mm notochord length within 6 days after hatching (Johns et al. 1981). No data on larval feeding habits is available.

Larvae of summer flounder are transported to estuarine nursery areas by currents. Greater densities of young fish were found in or near inlets, and greater numbers were captured during periods of the full moon (Williams and Deubler 1968).

In larval winter flounder (7 mm TL), the digestive tract is completely developed; the eyes are pigmented; and the mouth is fully functional (Sullivan 1914).

Sullivan (1914), who described the winter flounder larva from hatching to the end of the second month in the laboratory, divided its larval history into four stages which he selected to show diagnostic characteristics for identification.

Stage I - A group of dark pigment spots on the posterior half of the body is the most important character for identification. The notochord is present as a straight tube. Yolk absorption is gradual and varies with temperature.

Stage II - Yolk absorbed, age 12 days, length 5 mm.

Stage III - Metamorphosing larva 5-7 weeks old and 5.8 mm long.

Stage IV - Postlarva about 8 weeks old and 6.5 mm long; average body depth 2.75 mm.

Juveniles

Young summer flounder are 16 mm long when they first move into estuaries (Weinstein et al. 1980). In the Cape Fear River Estuary, North Carolina, postlarvae first entered the marshes in March and April (Weinstein 1979). Prior to late summer, juvenile summer flounder were randomly distributed in an estuary, but in late summer and early fall, they were more abundant in an estuarine sea grass bed than in an adjacent tidal marsh creek (Weinstein and Brooks 1983).

No postlarval summer flounder have been collected at salinities below 11 ppt in the Neuse River basin, North Carolina (Keup and Bayless 1964). However, juveniles were prevalent at higher salinities (Powell and Schwartz 1979). Pamlico Sound and adjacent estuaries are important nursery areas for summer flounder (Powell and Schwartz 1977). Yearlings move to the ocean in summer, but underyearlings remain in the estuaries (Powell and Schwartz 1977).

For the first summer, young-of-year winter flounder remain in shallow waters of bays and estuaries where they were spawned. Sandy coves appear to be preferred habitats of these fish (Hildebrand and Schroeder 1928).

The juveniles are preyed upon by summer flounder, striped bass, bluefish, and other species of fish of larger size; cormorants and harbor seals are also predators. The young are found from June through November from Mystic River, Connecticut, to Long Island Sound. In the Upper Mystic Estuary and Long Island Sound, between July and February, the average length of the young was 23 mm TL (Pearcy 1962). Juveniles have been observed year-round in Long Island Sound and are abundant from June to October in Shinnecock and Peconic Bay, Long Island. March through November is a peak period in the Delaware River Estuary. Off Massachusetts, only about 73% of the juveniles moved offshore in the spring and summer seaward migration (Howe et al. 1976). In Narragansett Bay, Rhode Island, smaller fish (10-20 cm long) do not migrate beyond the headlands in spring (Jeffries and Johnson 1974).

See Figures 3 and 4 for general development of both species.

Adults

Saila et al. (1965) prepared age-weight tables for winter flounder caught in Charlestown Pond and Narragansett Bay, Rhode Island. The average weight of 12-year-old specimens was calculated to be 874 g. The largest recorded adult was 570 mm (TL) and was probably considerably older than 12 years (Bigelow and Schroeder 1953).

Off southern Massachusetts, winter flounder moved seaward to deeper water in the spring and summer months, but usually remained within the 55-m depth contour (Howe and Coates 1975). This seaward movement may have been an avoidance of the temperature rise in the nearshore waters.

Annual natural mortality rate for winter flounder in the Mid-Atlantic Region was estimated at 27% (Howe and Coates 1975). Winter flounder dominated the catch of a research trawl and represented 50%-90% of all individuals in Narragansett Bay (Jeffries and Johnson 1974).

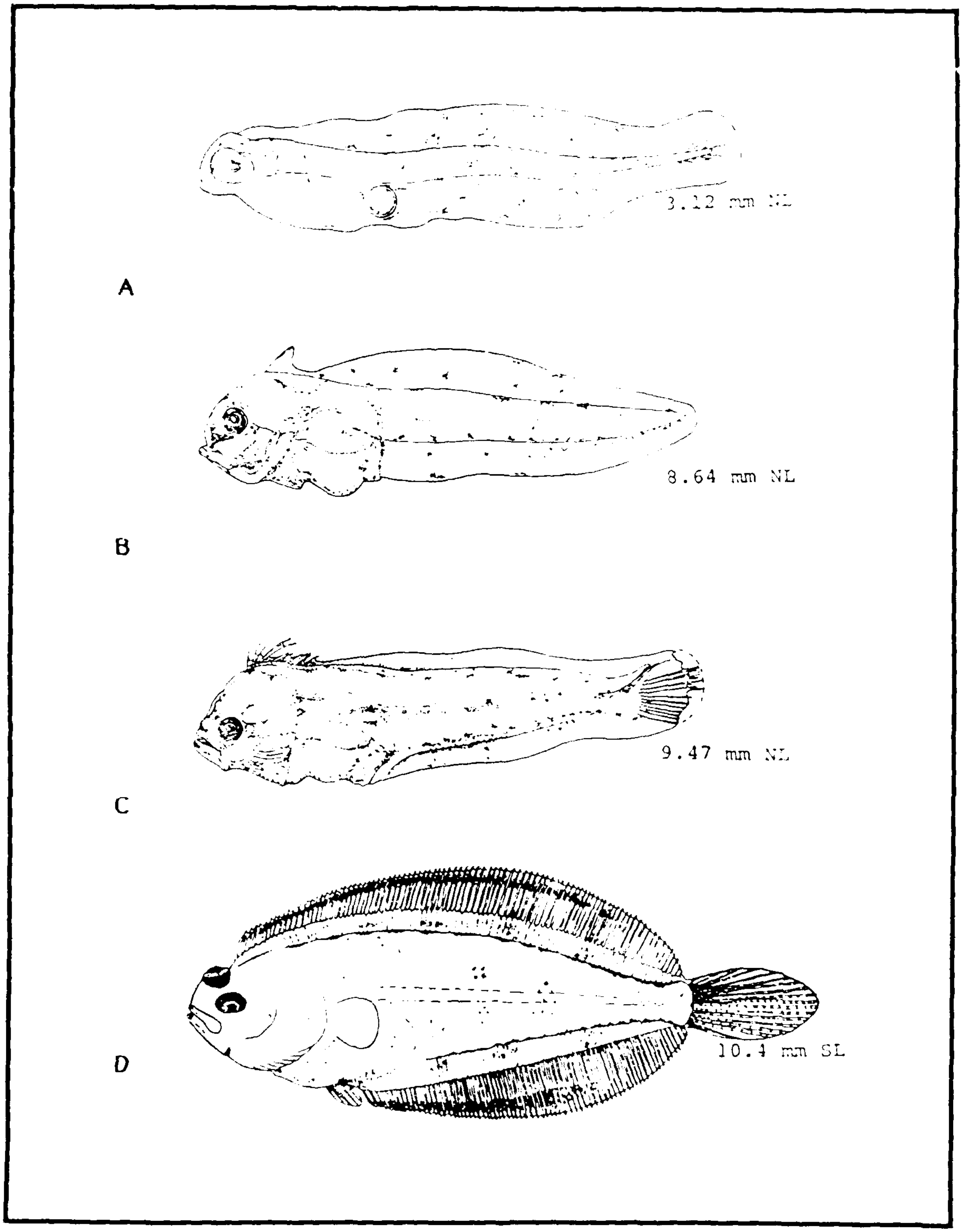


Figure 3. The general development for the summer flounder from hatching to adult. (Martin and Drewry 1978).

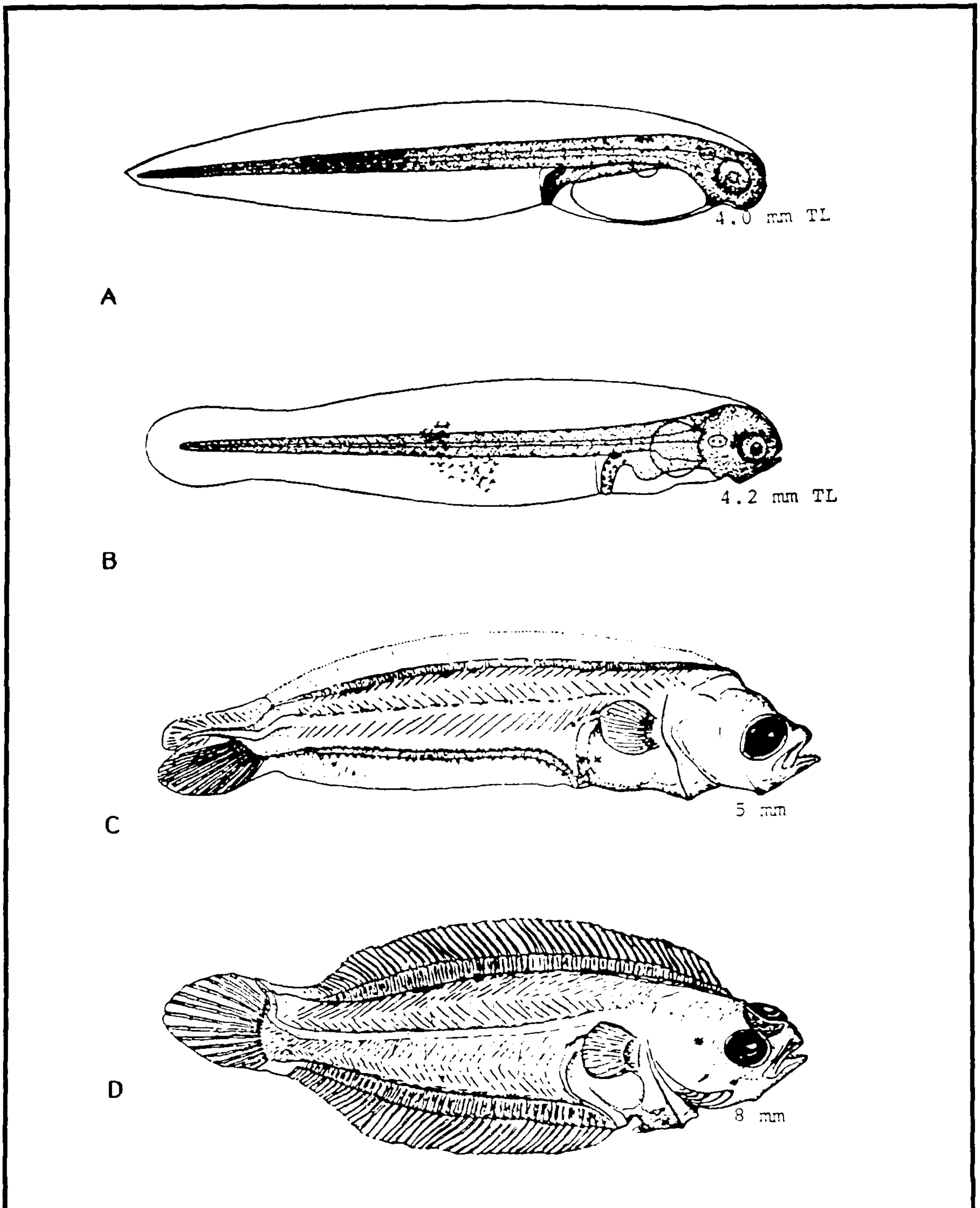


Figure 4. The general development for winter flounder from hatching to adult: A. newly hatched; B. 19 day larva; C. larva; D. juvenile (Martin and Drewry 1978).

Table 1. Weight-length regressions for summer flounder, where $\log_{10}$ weight (g) = a + b $\log_{10}$ length (mm) and r = correlation coefficient (Rogers and Van Den Avyle 1983).

Location and source	a	b	r
Pamlico Sound, North Carolina (Powell 1974)	-5.254	3.099	0.99
Mid Atlantic Bight (Wilk et al. 1978)			
Males	-5.289	3.126	0.96
Females	-5.578	3.226	0.98

GROWTH CHARACTERISTICS

Growth Rates and Length-Weight Relationships

In the Mid-Atlantic Region, growth rate of age I+ summer flounder decreases from north to south. A substantial shift in size at age I from 26 mm in New Jersey to 16 mm in South Carolina may result from differences in growth rates and spawning times; peak spawning in New Jersey is in November while it may occur as late as March in South Carolina (Smith et al. 1981). Growth of young-of-the-year ceased toward the end of their first year in fall and did not resume again until spring when the fish were yearlings (Powell and Schwartz 1977). Table 1 shows the length-weight relationships of summer flounder for Pamlico Sound, North Carolina, and the Mid-Atlantic Bight (Rogers and Van Den Avyle 1983).

Pearcy (1962) published comprehensive data on growth rates of young-of-the-year winter flounder from the Mystic River Estuary and noted seasonal changes in growth. Because metamorphosis was not completed until June, growth during the first 2 months was underestimated and was excluded from analysis. Growth of otoliths after deposition of the opaque center was variable; consequently the age of the young-of-the-year cannot be determined on the basis of otolith characteristics. Mean daily growth rates of winter flounder (in dry weight) were greater at 3 °C (10.1%) than at 5 °C (5.8%) or at 2 °C (2.6%), as shown by Laurence (1975).

Growth in weight for winter flounder was estimated by Pearcy (1962) who took average length of flounder in millimeters at the beginning of each month and converted it to weight in grams by the formula: $W=0.000017 \times L^3$ (Figure 5). Females are generally larger than males of the

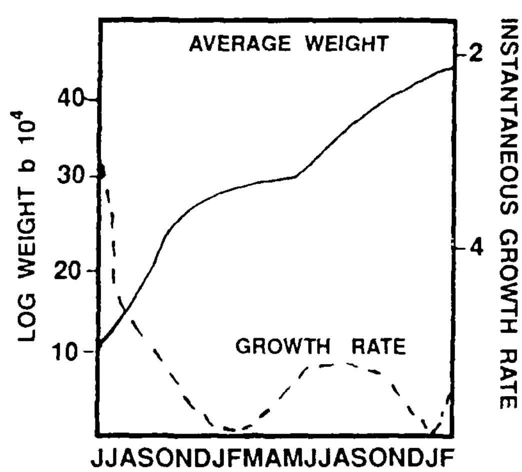


Figure 5. Average monthly weight gain for winter flounder in the Mystic River estuary (Pearcy 1962).

Table 2. Estimated length (mm TL) at age for winter flounder south of Cape Cod off Massachusetts (Howe and Coates 1975).

	Length (mm TL)	
Age	Males	Females
III	252	294
IV	301	350
V	340	390
VI	370	418
VII	393	438
VIII	411	452
IX	425	462
X	436	469
XI	445	474
XII	452	478

same age (Table 2) and grow significantly faster (Howe and Coates 1975).

THE FISHERY

Commercial Fisheries

In the late 1920's, as trawlers from northern ports moved south to exploit flounders and other species, the Cape Hatteras winter trawl fishery was initiated (Pearson 1932).

The average total annual landings for 1974 through 1978 in North Carolina were about 5.4 million kg, valued at $9.7 million (National Marine Fisheries Service 1980).

Edwards (1968) computed biomass of winter flounder on the Continental Shelf of New England by calculating the average catch in pounds per tow made by the 1963-66 groundfish survey using a "36 Yankee" trawl (0.5 inch cod end liner). Biomass was calculated by multiplying catch per tow by a correction factor which was the number of square miles for each zone divided by the area swept by the net in each tow. After the use of a second correction factor that eliminated remaining biases, standing crop for inshore waters of New England was estimated at 90 million pounds. Off southeastern Massachusetts, the winter flounder supports a coastal ground fishery in spring and autumn and an offshore fishery in summer (Howe et al. 1976). In a nearby area, fishing pressure was not correlated with depression in abundance of the inshore spawning stock (Jeffries and Johnson 1974).

Smolowitz (1983) demonstrated that, when used to catch winter founder, trawl nets with an average mesh size of 133 mm in the cod end (large mesh) decreased weight of discarded fish by 73% compared to nets averaging 103 mm in the cod end (small mesh).

Recreational Fisheries

Compared to catches in the Mid-Atlantic Bight, the recreational catch of summer flounder in the South Atlantic Bight is minor. In the South Atlantic Bight, North Carolina fishermen take 72% of the total catch. Fish less than five years old make up most of recreational catch in the Mid-Atlantic Bight.

Briggs (1965), who calculated catch rate of winter flounder per unit of effort (16-20 fish/angler/trip) by sportsmen fishing from five types of boats in four locations around Long Island for each month in 1961-63, showed that catch was highest in spring and lowest in summer.

Population Dynamics

Identification of the summer and winter flounder stocks and stock-specific biological traits is necessary for proper management, since genetically distinct stocks can have different rates of recruitment, growth, and mortality. The existence of three spawning populations was

proposed by Smith (1973) (one each from: Cape Cod to Delaware Bay; Virginia to Cape Hatteras, North Carolina; Cape Hatteras to Cape Lookout, North Carolina). Wilk et al. (1980) used discriminant analysis of morphometric characters to conclude that summer flounder from the Mid-Atlantic and South Atlantic Bights constitute two separate stocks divided by Cape Hatteras. The distribution of juveniles in Pamlico Sound is ubiquitous, and the estuary is accessible to both stocks. Juveniles in Pamlico Sound may exit to join the stock offshore to which they belong.

Pierce and Howe (1977) suggest; on the basis of fin ray counts, that winter flounder south of Cape Cod (including Martha's Vineyard but not Buzzards Bay) be managed as a unit stock. Saila (1962a, b), who compared sex ratios of winter flounder in Narragansett Bay, Rhode Island, with those from Charlestown Pond, Rhode Island, concluded that the higher proportion of females than males in the catch was due to catch selectivity for larger fish: females are considerably larger than males and the market preference is for larger fish.

ECOLOGICAL ROLE

Food Habits

It has been suggested that zooplankton and small crustaceans are eaten by larval and postlarval summer flounder, but supporting data is lacking. Mysid shrimp and small fish are the diet of juveniles, and adults feed on fish and mysid and decapod crustaceans (Hildebrand and Schroeder 1928; Smith and Daiber 1977; Powell and Schwartz 1979).

Sullivan (1914) stated that winter flounder larvae did not eat until after yolk absorption. Pearcy (1962) presents a detailed account of larval and young juvenile feeding habits. Throughout their range, adults maintained a varied diet from polychaetes to fish eggs. Their diet is related to size: the larger the individual, the greater the size of the food item to be consumed. The major food types of winter flounder were polychaetes and amphipods for fish 11-26 cm long from April to October (Worobec 1984). Predominant sizes of invertebrates eaten were similar to predominant sizes in the habitat for winter flounder 25-29 cm long, but fish 30-35 cm long selectively chose larger prey (Levings 1974). Winter flounder in Canada did not feed until after spawning at the start of the seaward migration, when they began feeding on polychaetes and large amphipods (Jeffries and Johnson 1974).

Feeding Behavior

Adult summer flounder feed in estuaries and shelf waters and are more active during daylight hours (Olla et al. 1972; Smith and Daiber 1977). Summer flounder can feed equally well in the water column or on the bottom. Bottom feeding is always preceded by an active search, and benthic prey is usually stalked. Searching, stalking, active eye motion, and visual fixation on prey during the day indicate that summer flounder are primarily visual feeders then (Olla et al. 1972).

Winter flounder feed partly by sight. They lie still on the bottom just before lunging at prey. They are inactive from within 30 minutes after evening twilight until the beginning of morning twilight. Fish feed throughout the day (Olla et al. 1969).

Parasites

The microsporidean protozoan *Glugea stephani* infected [illegible]% of winter flounder sampled from the Mid-Atlantic Region; the infection is present year-round (Takvorian and Cali 1984).

ENVIRONMENTAL REQUIREMENTS

Temperature and Salinity

Although the summer flounder is tolerant of a wide range of chemical and physical conditions, such factors do influence its biology. A thermal shock (temperature increase) of 20 °C above an acclimation temperature of about 15 °C caused no mortality in early embryo stage eggs of summer flounder, but a shock of 16 °C for 16 minutes or 18 °C for 2 minutes caused mortality in late embryo stage eggs (Itzkowitz et al. 1983). Following a thermal shock of 10 °C above an acclimation temperature of 15 °C, larvae were actually less susceptible to predation than control larvae (Deacutis 1978). In the Mid-Atlantic Bight north of Chesapeake Bay, spawning and the offshore limits of migration coincide with the inshore edge of the mass of cold bottom water which disappears along with the thermocline in November (Smith 1973). Growth efficiency, feeding rate, and assimilation efficiency of juveniles is directly related to temperature under laboratory conditions (Peters and Angelovic 1971). Growth rate and growth efficiency are greatest at salinities >10 ppt. Summer flounder were found at salinities of 12-35 ppt in Pamlico Sound, over sand or sandy mud rather than silt or clay (Powell and Schwartz 1977). Pamlico Sound is unusual, however, because tides are minor and salinities are uniform throughout much of the sound. In estuaries with major tides that affect the horizontal salinity gradient, or estuaries with different substrate type-salinity relationships, the distribution of summer flounder might be different (Powell and Schwartz 1977).

Viable hatching of winter flounder eggs was optimal at 3 °C and 15-25 ppt (Rogers 1976). Yearling winter flounder prefer a temperature of 18.5 °C (Casterlin and Reynolds 1982). After acclimation at 5 °C, winter flounder larvae suffered low mortality during 4-64 minutes of exposure to a thermal shock of 22 °C (Itzkowitz and Schubel 1983). Thermal shocks of 28-30 °C for 4 minutes produced 100% mortality. Larvae entrained in the cooling water systems of power plants encounter thermal shocks of 5-23 °C (Itzkowitz and Schubel 1983). Winter flounder (about 10 cm long) had an upper incipient lethal temperature (after 48 hours) of about 29 °C after acclimation at either 28 °C or 22 °C (Hoff and Westman 1966). Upper incipient lethal temperatures were 19 °C after acclimation at 4 °C and 26.5 °C after acclimation at 20 °C (McCracken 1963). Winter flounder become inactive above 22.2 °C (Olla et al. 1969).

Lower incipient lethal temperatures (for 48 hr exposures) after acclimation at 28 °C and 21 °C were (respectively) 5.4 °C and 1.0 °C (Hoff and Westman 1966). In a seven year study, the winter flounder catch was negatively correlated with degree-days (an estimate related to average temperature) over the previous 30 months (Jeffries and Johnson 1974). A slight increase in average temperature (<0.5 °C) may hinder recruitment to the fishery, probably through indirect effects on the ecosystem (Jeffries and Johnson 1974).

Pollution

In winter flounder, fin rot disease occurred more frequently in a polluted area (incidence = 14%-16%) than in unpolluted waters (3%) in the Mid-Atlantic Region (Ziskowski and Murchelano 1975). Fin rot prevalence was relatively low in southern New England, ten offshore waters of the New York Bight, and on Georges Bank compared to prevalence in the Gulf of Maine. Lymphocystis (a viral disease) was most common in offshore waters between Delaware Bay and Massachusetts (Ziskowski et al. 1987). In the laboratory, mortality in the summer was significantly increased in winter

flounder exposed to oiled sediments. Feeding rates were significantly less in fish exposed to fresh oil in sediments, but little or no response to oiled sediments aged for 1 year was observed. Reduced feeding in response to oil contamination could deplete reserves that winter flounder need for sustenance and reproduction in winter (Fletcher et al 1981). No feeding or mortality occurred in winter.

Summer flounder larvae survived exposure to high concentrations of sea water sediment extract from Charleston Harbor, South Carolina, better than did pinfish larvae; survival was 100% (Hoss et al. 1974). The sediment extract probably contained any contaminants that would be in the outfall (runoff) from a dyked disposal area for dredged material taken from the harbor (Hoss et al. 1974). Fin rot disease in summer flounder was slightly more common in the inshore waters of the New York and New Jersey coasts than in more offshore waters (Ziskowski et al. 1987). In a model of the effects of pollution on a multispecies group of coastal fishes, summer flounder showed moderate effects (depression of abundance) but took 10-12 years to recover (Schaaf et al. 1987).

LITERATURE CITED

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv. Fish. Bull. 53. 577 pp.

Breder, C.M., Jr. 1922. Description of the spawning habits of Pseudopleuronectes americanus in captivity. Copeia 102:3-4.

Breder, C.M., Jr. 1924. Some embryonic and larval stages of the winter flounder. Bull. U.S. Bur. Fish. 38:311-315.

Briggs, P.T. 1965. The sport fisheries for winter flounder in several bays of Long Island, N.Y. Fish Game J. 12:48-70.

Burton, M.P., and D.R. Idler. 1984. The reproductive cycle in winter flounder, Pleuronectes americanus. Can. J. Zool. 62:2563-2567.

Casterlin, M.E., and W.W. Reynolds. 1982. Thermoregulatory behavior and diel activity of yearling winter flounder, Pseudopleuronectes americanus. Environ. Biol. Fishes 7:177-180.

Deacutis, C.F. 1978. Effect of thermal shock on predator avoidance by larvae of two fish species. Trans. Am. Fish. Soc. 107:632-635.

Dickie, L.M., and F.D. McCracken. 1955. Isopleth diagrams to predict equilibrium yields of a small flounder fishery. J. Fish. Res. Board Can. 12:187-209.

Deubler, E.E., Jr. 1958. A comparative study of the postlarvae of three flounders (Paralichthys) in North Carolina. Copeia 1958:112-116.

Edwards, R.L. 1968. Fishery resources of the North Atlantic area. Pages 52-60 in D. Gilbert, ed. The future of the fishing industry of United States. Univ. Wash. Publ. Fish. New Ser. 4.

Fletcher, G.L., J.W. Kiceniuk, and V.P. Williams. 1981. Effects of oiled sediments on mortality, feeding, and growth of winter flounder (Pseudopleuronectes americanus). Mar. Ecol. Prog. Ser. 4:91-96.

Hildebrand, S.F., and W.C. Schroeder. 1928. Fishes of the Chesapeake Bay. U.S. Bureau of Fisheries 1024:366 pp.

Hoff, J.G., and J.R. Westman. 1966. The temperature tolerances of three species of marine fishes. J. Mar. Res. 24:131-140.

Hoss, D.E., L.C. Coston, and W.E. Schaaf. 1974. Effects of seawater extracts of sediments from Charleston Harbor, S.C., on larval estuarine fishes. Estuarine Coastal Mar. Sci. 2:323-328.

Howe, A.B., and P.G. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. Trans. Am. Fish. Soc. 104:13-29.

Howe, A.B., P.G. Coates, and D.E. Pierce. 1976. Winter flounder

estuarine year-class abundance, mortality, and recruitment. Trans. Am. Fish. Soc. 105:647-657.

Itzkowitz, N., and J.R. Schubel. 1983. Tolerance of five-day-old winter flounder, Pseudopleuronectes americanus, larvae to thermal shock. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 81:913-916.

Itzkowitz, N., J.R. Schubel, and P.M.J. Woodhead. 1983. Responses of summer flounder, Paralichthys dentatus, embryos to thermal shock. Environ. Biol. Fishes 8:125-135.

Jeffries, H.P., and W.C. Johnson. 1974. Seasonal distributions of bottom fishes in the Narragansett Bay area: seven-year variations in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Board Can. 31:1057-1066.

Johns, D.M., W.H. Howell, and G. Klein-MacPhee. 1981. Yolk utilization and growth to yolk sac absorption in summer flounder (Paralichthys dentatus) larvae at constant and cyclic temperatures. Mar. Biol. (Berl.) 63:301-330.

Kennedy, V.S., and D.H. Steele. 1971. The winter flounder (Pseudopleuronectes americanus) in Long Pond, Conception Bay, Newfoundland. J. Fish. Res. Board Can. 28:1153-1165.

Keup, L., and J. Bayless. 1964. Fish distribution at varying salinities in Neuse River basin, North Carolina. Chesapeake Sci. 5:119-123.

Laurence, G.C. 1975. Laboratory growth and metabolism of the winter flounder Pseudopleuronectes americanus from hatching through metamorphosis at three temperatures. Mar. Biol. (Berl.) 32:223-229.

Levings, C.D. 1974. Seasonal changes in feeding and particle selection by winter flounder (Pseudopleuronectes americanus). Trans. Am. Fish. Soc. 103:828-832.

Martin, F.D., and G.E. Drewry. 1978. Development of fishes of the Mid-Atlantic Bight, an atlas of egg, larval, and juvenile stages. Vol. VI, Stromateidae through Ogcocephalidae. U.S. Fish. Wildl. Serv. Biol. Serv. Program FWS/OBS-78/12. 416 pp.

McCracken, F.D. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic coast. J. Fish. Res. Board Can. 20.551-586.

Morse, W.W. 1981. Reproduction of the summer flounder, Paralichthys dentatus (L.). J. Fish Biol. 19:189-203.

National Marine Fisheries Service. 1980. Fishery Statistics of the United States, 1979. U.S. Natl. Mar. Fish. Serv. Curr. Fish. Stat. No. 8000.

National Marine Fisheries Service. 1987a. Fisheries of the United States, 1986. U.S. Natl. Mar. Fish. Serv. Curr. Fish. Stat. 8385.

National Marine Fisheries Service. 1987b. Marine recreational fishery statistics survey, Atlantic and gulf coasts, 1986. U.S. Natl. Mar. Fish. Serv. Curr. Fish. Stat. 8392.

Olla, B.L., R. Wicklund, and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Trans. Am. Fish. Soc. 98:717-720.

Olla, B.L., C.E. Samet, and A.L. Studholme. 1972. Activity and feeding behavior of the summer flounder (Paralichthys dentatus) under controlled laboratory conditions. Fish. Bull. 70:1127-1136.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder Pseudopleuronectes americanus (Walbaum). Bull. Bingham Oceanogr. Collect., Yale Univ. 18(1). 78 pp.

Pearson, J.C. 1932. Winter trawl fishery off the Virginia and North Carolina coasts. U.S. Bur. Fish. Invest. Rep. 10. 31 pp.

Peters, D.S., and J.W. Angelovic. 1971. Effect of temperature, salinity, and food availability on growth and energy utilization of juvenile summer flounder, Paralichthys dentatus. Pages 545-554 in D.J. Nelson, ed. Radionuclides in ecosystems. National Symposium on Radioecology, Oak Ridge, Tenn.

Pierce, D.E., and A.B. Howe. 1977. A further study on winter flounder group identification off Massachusetts. Trans. Am. Fish. Soc. 106:131-139.

Powell, A.B. 1974. Biology of the summer flounder, Paralichthys dentatus, in Pamlico Sound and adjacent waters, with comments on P. lethostigma and P. albigutta. M.S. Thesis. University of North Carolina, Chapel Hill. 145 pp.

Powell, A.B., and F.J. Schwartz. 1977. Distribution of paralichthid flounders (Bothidae: Paralichthys) in North Carolina estuaries. Chesapeake Sci. 18:334-339.

[illegible], and [illegible] Schwartz. 1979. Food of Paralichthys dentatus and P. lethostigma (Pisces: Bothidae) in North Carolina estuaries. Estuaries 2:276-279.

[illegible], and M. Castagna. 1970. Marine fishes of Virginia's eastern shore (inlet and marsh, seaside waters). Chesapeake Sci. 11:235-248.

Rogers, C.A. 1976. Effects of temperature and salinity on the survival of winter flounder embryos. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 74:52-58.

Rogers, S.G., and M.J. Van Den Avyle. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic)--summer flounder. U.S. Fish. Wildl. Serv. FWS/OBS-82/11.15. U.S. Army Corps of Engineers, TR EL-82-4. 14 pp.

Saila, S.B. 1961. A study of winter flounder movements. Limnol. Oceanogr. 6:292-298.

Saila, S.B. 1962a. The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf Caribb. Fish. Inst. 14:95-109.

Saila, S.B. 1962b. Proposed hurricane barriers related to winter flounder movements in Narragansett Bay. Trans. Am. Fish. Soc. 91:189-195.

Saila, S.B., D.B. Horton, and R.J. Berry. 1965. Estimates of the theoretical biomass of juvenile winter flounder, Pseudopleuronectes americanus (Walbaum), required for a fishery in Rhode Island. J. Fish. Res. Board Can. 22:945-995.

Scarlett, P.G. 1981. Fishery management plan for the summer flounder fishery. Atlantic States Marine Fisheries Commission Management Report 81-1. Washington, D.C. 80 pp.

Schaaf, W.E., D.S. Peters, D.S. Vaughan, L. Coston-Clements, and C.W. Krouse. 1987. Fish population responses to chronic and acute pollution: the influence of life history strategies. Estuaries 10:267-275.

Smith, R.W., and F.C. Daiber. 1977. Biology of the summer flounder, Paralichthys dentatus, in Delaware Bay. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 75:823-830.

Smith, R.W., L.M. Dery, P.J. Scarlett, and A. Jearld, Jr. 1981. Proceedings of the summer flounder (Paralichthys dentatus) age and growth workshop 20-21 May 1980, Northeast Fishery Center, Woods Hole, Massachusetts. NOAA Tech. Memo. NMFS-F/NEC-11. 31 pp.

Smith, W.G. 1973. The distribution of summer flounder, Paralichthys dentatus, eggs and larvae on the Continental Shelf between Cape Cod and Cape Lookout, 1965-1966. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 71:527-548.

Smolowitz, R.J. 1983. Mesh size and the New England ground fishery--applications and implications. NOAA Tech. Rep. NMFS-SSRF-771. 60 pp.

Sullivan, W.E. 1914. A description of the young stages of the winter flounder (Pseudopleuronectes americanus Walbaum). Trans. Am. Fish. Soc. 44:125-136.

Takvorian, P.M., and A. Cali. 1984. Seasonal prevalence of the microsporidean, Glugea stephani (Hagenmuller), in winter flounder, Pseudopleuronectes americanus (Walbaum), from the New York-New Jersey Lower Bay Complex. J. Fish Biol. 24:655-663.

Topp, R.W. 1968. An estimate of fecundity of the winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Board Can. 25:1299-1302.

Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfishes, Cape Fear River, North Carolina. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 77:339-357.

Weinstein, M.P., and H.A. Brooks. 1983. Comparative ecology of nekton residing in a tidal creek and adjacent seagrass meadow: community composition and structure. Mar. Ecol. Prog. Ser. 12:15-27.

Weinstein, M.P., S.L. Weiss, R.G. Hodson, and L.R. Gerry. 1980. Retention of three taxa of post larval fishes in an intensively flushed tidal estuary, Cape Fear River, North Carolina. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 78:419-436.

Wilk, S.J., W.W. Morse, and D.E. Ralph. 1978. Length-weight relationships of fishes collected in the New York Bight. Bull. N.J. Acad. Sci. 23:58-64.

Wilk, S.W., W.G. Smith, D.E. Ralph, and J. Sibunka. 1980. Population structure of summer flounder between New York and Florida based on linear discriminant analysis. Trans. Am. Fish. Soc. 109:265-271.

Williams, A.B., and E.E. Deubler. 1968. A ten-year study of meroplankton in North Carolina estuaries: assessment of environmental factors and sampling success among bothid flounders and penaeid shrimps. Chesapeake Sci. 9:27-41.

Worobec, M.N. 1984. Field estimates of the daily ration of winter flounder, Pseudopleuronectes americanus (Walbaum), in a southern New England salt pond. J. Exp. Mar. Biol. Ecol. 77:183-196.

Ziskowski, J., and R. Murchelano. 1975. Fin erosion in winter flounder. Mar. Pollut. Bull. 6:26-29.

Ziskowski, J.J., L. Despres-Patanjo, R.A. Murchelano, A.B. Howe, D. Ralph, and S. Atran. 1987. Disease in commercially valuable fish stocks in the northwest Atlantic. Mar. Pollut. Bull. 18:496-504.

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. Biological Report 82(11.112)*

2.

3. Recipient's Accession No

4. Title and Subtitle
Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)--Summer and Winter Flounder

5. Report Date
August 1989

6.

7. Author(s)
Barbara H. Grimes, Melvin T. Huish, and J. Howard Kerby[a]; David Moran[b]

8. Performing Organization Rept. No

9. Performing Organization Name and Address
a North Carolina Cooperative Fishery Research Unit
Department of Zoology, Box 7617
North Carolina State University
Raleigh, NC 27695

b National Wetlands Research Center
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No
(C)
(G)

12. Sponsoring Organization Name and Address
U.S. Department of the Interior
Fish and Wildlife Service
National Wetlands Research Center
Washington, DC 20240

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

13. Type of Report & Period Covered

14.

15. Supplementary Notes
U.S. Army Corps of Engineers Report No. TR EL-82-4

16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal species. They are designed to assist in environmental impact assessments. The summer flounder supports an important commercial and recreational fishery in the Mid-Atlantic and are important constituent of estuarine and continental shelf systems throughout the region. Summer flounder spawning begins in September and winter flounder spawning begins in June. Summer flounder eggs are pelagic whereas winter flounder eggs are demersal. Summer flounder larvae are more abundant in inlets, and juveniles are found in estuarine seagrass beds in salinities ≥12 ppt. Winter flounder juveniles are abundant in shallow bays and estuaries, moving seaward in spring and summer. Growth of winter flounder and summer flounder is seasonal. There are probably three spawning populations of both species which produce a complex stock pattern. Summer flounder are tolerant of a wide range of chemical and physical factors, but prefer >10 ppt salinities. Winter flounder optimal temperature is 18.5 °C. Diseases of winter flounder are more prevalent in polluted waters. Summer flounder are tolerant of sediments laden with contaminants.

17. Document Analysis a. Descriptors

a) Flounder, Fisheries, Salinity, Growth, Feeding habits, Temperature, Life cycles

b. Identifiers/Open-Ended Terms

b) *Paralichthys dentatus*, *Pseudopleuronectes americanus*, Summer flounder, Winter flounder

c. COSATI Field/Group

18. Availability Statement
Unlimited Distribution

19. Security Class (This Report)
Unclassified

20. Security Class (This Page)
Unclassified

21. No of Pages
18

22. Price

(See ANSI-Z39 18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce